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LEAF AREA INDEX MEASUREMENTS FOR *PINUS BRUTIA* TEN. PLANTATIONS IN NORTHERN IRAQI

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ABSTRACT

The surface area of the leaves of trees that perform photosynthesis is expressed by the leaf area index (LAI) for pine trees with different densities, using direct methods by collecting field data in 2022 from (30) samples, and measurements were taken of the diameter at breast height for each sample and the total height, crown center height, crown width, and number of trees. Through field data and laboratory analysis of the relationships between the structure of tree elements, it was found that the leaf area index showed an inverse relationship with the distances between trees and that increasing the distance between trees reduces the crown coverage of trees and thus is reflected in the leaf area index of the tree. At low densities, it decreases and increases with increasing tree density. This also applies to the relationship between the dry weight of leaves and the distances between trees, as an inverse relationship showed, and this was also clear for the relationship between the dry weight of leaves and the average diameter and height of the trees in that tree. A set of equations was reached that was tested using multiple statistical standards, and it was the equation of the dry weight of pine tree leaves per unit area, the equation of the surface area of pine tree leaves per unit area, as well as the leaf area index of pine trees (LAI).

INTRODUCTION

Forests provide many wood products with high economic values that are required by society, in addition to environmental, tourism, and protective services. Forests absorb carbon dioxide, purify the air, and reduce global warming) Solís-Silvan, *et al* 2022) (Ariza *et al* 2019), in addition to helping maintain the vital balance of many of living organisms, whether plant or animal, trees are of great importance in preserving the environment from various industrial pollutants, as well as, they work to improve the soil by decomposing tree debris into organic materials continuously and periodically. Therefore, trees are the main factor in maintaining and sustaining environmental balance (Chen *et al* 1997), tree leaves are considered the main component of the tree's crown canopy and are responsible for the photosynthesis processes that need to absorb light and convert it into chemical energy (Ahmed, and. Younis, 2020).

They are also considered the main responsible for all the physiological processes that occur in the tree, so there is great importance. In studying the surface area of tree leaves, and estimating that area, we can monitor the vitality of trees and the processes that fundamentally affect the growth, development, and continuity of trees (Al-Allaf *et al* 2023).

A group of trees growing in a location forms a crown canopy with a variable local climate that depends on the density of the crowns of those trees. The crown canopy of trees has A mutual relationship with the atmosphere, which also controls the deflection of rainfall, the reflection of sunlight, and the amount of rainfall reaching the forest floor. The crown canopy is an essential element in the biogeochemical cycles in the ecosystem (Davidson, et al,2000) and(Kurdy . and. Saeed, 2021), and the surface area of the crown canopy changes dramatically. Continuous biotic and abiotic factors (Drought, fires, rainstorms, competition between trees, etc.) cause differences in tree growth and productivity (Correia, *et al* (2017).

Therefore, measuring the surface area of the crown canopy is an important matter for the forest administrator. At the same time, measuring the surface area of leaves is not an easy process. This is because the distribution of leaves in tree crowns varies according to the types and shapes of the leaves. This means that there is a large spatial variation in the distribution, as well as the changes occurring in the distribution due to the difference in time, and this results from the interaction between the elements of the ecosystem and the atmosphere on an ongoing basis. Therefore, we notice that there are differences in area. The surface area of leaves from one period of time to another, as well as between one type and another, also varies according to the type of tree. It must be noted that the surface area of leaves is affected by the environmental factors of the site, especially temperatures and the abundance of moisture in the air and soil, in addition to the genetic characteristics of the type of tree itself (Correia, *et al* 2017).

In general, it is divided into methods that rely on indirect and direct field measurements and those that rely on taking samples of leaves and calculating their surface area using mathematical laws for geometric shapes that are similar to the shape of the leaf. Therefore, this study came to estimate the surface area of leaves from naturally growing pine trees in northern Iraq, to estimate the Leaf Area Index for pine trees using ground inventory methods and mathematical equations.

MATERIALS AND METHODS

This study was conducted on Pine trees grown in zawita, Atrush and Sarsang in Dohuk Region Developing in northern Iraq, located on a latitude ranging between (N 36°43^' 52"3 -37°07'22.6") And longitude E (42° 48^' 32.8"-43 54' 40".2). These forests are far from Dohuk Governorate, a distance of (2-45) km.

The study site is characterized by being within the formations of the mountainous region in Iraq, in which different types of forest trees grow (Dewey, *et al* 2006), (Fang, *et al* 2019) samples were taken for each density to ensure representation of the community and increase the accuracy of the work. Random samples were taken from each layer, and after determining the samples on the ground sites of the trees, each sample was determined with a radius of (17.9) m and a total area of (1006) m. From each sample, measurements were taken of the diameter at breast height, the total height, the height of the crown center, and the crown width for all the trees in the sample, as well as the number of trees in the sample, as well as a measurement of the leaf area of the tree.

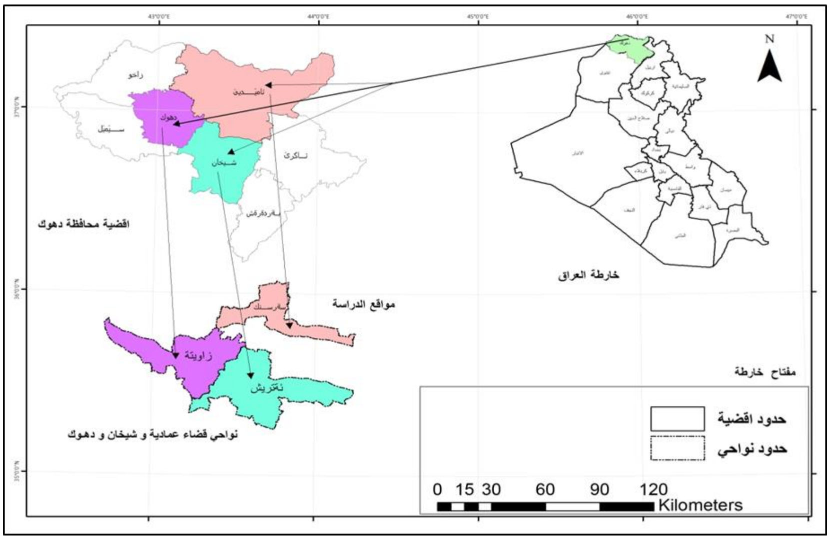

Figure (1): Study area in Dohuk Governate

The function is to divide the crown of a single sample into three equal parts and from each layer of the crown according to the number of branches for it. A branch was cut randomly from each layer, then the cut branch was stripped of leaves, and measurements of the wet weight of the leaves were taken in the field with a balance of accuracy (0.1) g After that, a secondary sample with a known wet weight was taken and placed inside paper and plastic bags, and the part number, the total wet weight of the branch leaves, and the weight of the secondary sample were written on it, and so it was done for all samples. I took 150 sheets of paper from each sample weighed them with a sensitive scale in the laboratory and recorded the weight. After calculating the wet weight of 150 sheets of each sample, these samples were taken and placed inside perforated paper bags to dry them completely at a temperature of 70°C until the weight was stable. We also performed several measurements on 150 leaves from each sample. These measurements consisted of estimating the diameter of the needle leaf using a device (Vernier Gilper) and measuring the diameter of each needle leaf from three different directions from an area that is approximately in the middle of the leaf. Also, the base measurement of the needle leaf is taken in the same way and from different directions. The averages for these are extracted. The measurements are represented by the diameter at half the leaf, the diameter at the base of the leaf, and then measuring the width of the two needles meeting on one leaf. The length is also measured for all the needle leaves and in each sample using a regular millimeter ruler. Relationships have been used to estimate the surface area.

v= $\pi \times r^2$
A=L×W
V=Volume (cm^3), A=area(cm^2), L=length(cm), and W=width(cm)

$$S_{\text{needles of Xulometric}} = 2\times L\left(1+\frac{\pi}{n}\right) \times \sqrt{\frac{\mathbf{v\times n}}{\boldsymbol{\pi}\times \mathbf{1}}}$$

$$Total\ Surface\ of\ Needles = S_{\text{needles of Xulometric}} + Surface\ Rectangle\ area1 + Surface\ Rectangle\ area\ 2$$

To calculate the leaf area index, we estimated the leaf mass area (LMA) through the following relationship:

$$Leaf\ Mass\ Per\ Area(LMA) = \frac{Dry\ weight\ of\ leaves\ sample/g}{Fresh\ weight/g}$$

Likewise, the leaf area index of the pine trees growing in the study area was calculated from the following equation:

$$Stand\ needles = \frac{\text{Total dry weight leaves}}{LMA}$$

Likewise, the leaf area index of the pine trees growing in the study area was calculated from the following equation:

$$Leaf\ Area\ Index(\ LAI) = \frac{\text{S stand needles}}{10000}$$

Therefore, the leaf area index $m^2\,m^{-2}$ was calculated as in Table (1).

Table (1): Total surface area of the tree.

No.	Wet weight of 150 leaves (g)	Dry weight 150 leaf(g)	Surface area of 150 leaf(m^2)	Surface area of secondary sample (m^2)	Surface area of the branch (m^2)	Branch lengths (m)	Surface area (1) (m^2)	The surface area of the function tree(m^2)
1	3.4249	3.1591	33309.56	2723196.82	10406502.15	50.74	4.63	234.66
2	2.5932	2.3894	27676.40	1963773.56	7705676.69	43.69	3.85	168.33
3	3.5671	3.2963	32354.81	1904771.41	8072602.65	78.57	3.23	253.71
4	4.9888	4.6132	43911.25	1813205.08	6795118.06	81.22	3.40	275.95
5	2.6891	2.4551	27173.07	1616783.01	5759789.48	28.10	2.88	80.93
6	3.5378	3.3408	36244.71	737638.96	2848105.99	47.88	1.90	90.9
7	4.9164	4.5494	42669.51	1414679.47	4478371.81	49.18	2.99	146.83
8	3.0225	2.7529	37377.57	1038781.10	4019093.55	50.42	2.68	135.11
9	3.5284	3.3077	33930.15	1134723.30	4596591.00	47.94	2.30	110.17
10	3.3789	3.1138	34067.77	705775.22	2702110.85	42.47	1.80	76.5
11	5.1373	4.7159	41614.05	583226.91	2422011.75	50.42	1.42	71.84
12	3.9372	3.6415	36347.89	3489663.32	13847870.31	38.30	5.54	212.15
13	2.8897	2.6911	27445.33	816797.03	3115225.89	50.74	2.08	105.37
14	5.1053	4.8265	42218.59	1041964.69	4134780.52	69.89	2.07	144.48
15	4.5735	4.2039	37085.29	1459571.93	5740982.91	51.73	2.87	148.49
16	3.6526	3.3112	32594.48	624654.66	2409382.25	65.72	1.61	105.56
17	2.5893	2.3825	25398.64	941671.28	3884394.02	42.15	2.28	96.32
18	4.0754	3.6862	42941.80	3582522.45	14625121.07	28.73	5.85	168.04
19	3.6599	3.3821	35669.65	1656832.29	6354439.14	47.88	3.74	178.95
20	2.4683	2.2885	24879.48	3427064.46	13869531.45	43.71	5.55	242.49
21	4.0288	3.6905	43974.93	3460100.48	13873147.35	63.17	5.55	350.55
22	4.2325	3.8021	40524.82	708526.09	2776656.30	54.59	1.85	101.05
23	3.5095	3.23	33437.65	724109.25	2953603.50	51.73	1.97	101.86
24	4.4442	4.0926	38484.81	2926930.78	11880914.30	57.76	4.75	274.5
25	4.4501	4.09	49183.28	2033600.04	2984087.01	60.00	1.99	119.36
26	2.7507	2.4992	26199.91	885807.84	3543231.37	67.03	2.08	139.7
27	3.6925	3.3333	31556.35	1589568.34	6477918.29	38.61	3.24	125.06
28	3.3373	3.1035	30800.05	627574.21	2325716.18	76.91	1.16	89.44
29	3.0338	2.7721	29813.95	1080998.91	4147104.92	102.47	1.66	169.97
30	3.3812	3.1162	41621.62	1083255.22	3963729.34	57.76	1.98	114.47

Statistical and graphical measures were used to test the equations that estimate the index of leaf area of pine trees, represented by the coefficient of determination, the measurement error attributed to the rate, and the analysis of the residuals.

RESULTS AND DISCUSSION

Stand structure forest

Forest trees are characterized by many characteristics, such as the total height of the trees and the diameter at Breast height, as well as the area of leaf coverage of the tree crowns and their crown canopy, in addition to the distances between the trees, and also the types of trees that make up the structure (Salim,et al 2023) (Hartoyo,et al 2022).

The difference in these elements leads to differences in the structure and functions that these trees perform [10] and there is also a significant relationship between the number and types of trees and their leaf area index (Unger, et al, 2013). Therefore, knowing the tree composition elements is essential for the sustainability of these resources and the provision of services and products on an ongoing basis. Therefore, this study was conducted on the trees of the pine tree growing continuously. Naturally in northern Iraq, using (30) samples with different densities represents the study area, as in Table (2).

Table (2): Some botanical characteristics of naturally growing pine trees in the northern of Iraq.

NO.	LAI/ $m^2.m^{-2}$	SAL/m^2	$\bar{D}$/cm	SP/m	N/tree	$\bar{H}$ /m	HP/m	wt/ha.
1	1.0061	225822	23.6	4.8	417	10.8	5.5	13890.1
2	1.2996	215785	8.2	3.4	824	4.9	1.7	22805.3
3	0.8055	139494	16.9	5.8	288	6.8	2.6	9318.1
4	1.2132	121492	7.1	5.1	387	4	2.2	16993.6
5	0.4052	185888	14	4.4	506	7.1	4.4	13749.5
6	0.5722	197082	11.8	3.9	645	8.9	2.6	23377.8
7	1.3602	284808	22.2	3.5	804	12.2	4	34306.2
8	0.7156	213496	15.6	3.9	655	6.4	3.2	24482.3
9	0.4995	176875	15.2	4.7	436	7.7	3.2	14793.5
10	0.6631	206108	13.1	3.3	874	5.1	2.2	29775.2
11	0.3609	152723	12.4	4.9	407	6.3	2.7	16936.9
12	0.6848	209911	27.1	5.7	298	13.8	2.7	10831.6
13	0.3195	176945	26.5	5.8	288	12.6	5.2	7904.2
14	0.7285	169492	14.4	4.8	417	7.8	2.3	17605.1
15	0.4724	123233	17.4	6.2	258	9.8	3.1	9568
16	1.3982	217437	8.5	2.9	1182	4.8	1.9	38526.6
17	0.4772	205674	21.6	4.5	486	10.8	2.8	12343.7
18	0.4114	174325	27.4	6.2	258	13	4.4	11078.9
19	1.3128	250900	20.3	3.7	715	10.6	4.6	25503.8
20	0.7890	184746	21	5.5	328	10.7	4.2	8160.4
21	0.95705	140727	18.	5.7	298	6.6	3.1	13104.5
22	0.775725	226074	16.5	3.6	735	7.7	2.3	29785.7
23	1.082985	219892	8.8	3.1	1013	5.5	1.8	33872.3
24	1.099964	150014	14.2	5.3	347	7.5	2.6	13354.2
25	0.93311	208629	9.4	3.4	864	5.3	2.8	42494.3
26	0.508934	132540	11.4	5.3	347	5.7	2.3	9091.3
27	0.638023	175393	16.8	4.7	436	7.1	2.3	13758.5
28	0.490354	145571	7.7	4.4	506	4.6	0.4	15584.8
29	0.62266	156679	19.1	5.8	288	9.8	2.1	8586.4

NO.	LAI/ $m^2.m^{-2}$	SAL/m^2	$\overline{D}$/cm	SP/m	N/tree	$\overline{H}$ /m	HP/m	wt/ha.
30	0.369191	146187	15.3	5	397	7	2	16523.7
Mean	0.765793	184464	16.1	4.6	523.466	8.07	2.9	18603.6
Min.	0.31951	121492	7.1	2.9	258	4.01	0.4	7904.2
Max.	1.398248	284808	27.4	6.2	1182	13.8	5.5	42494.3
S.D.	0.328416	43014	6.1	1.03	267.612	2.9	1.2	10307.2

LAI=leaf area index, SAL=surface area needles, $\overline{D}$=mean dimeter at breast height, sp=spacing between tree, N=Number of tree in hectare, $\overline{H}$= mean height, HP=height crown diameter, wt/ha=dry weight needles in hectare.

Through Table (2) we notice that there is a discrepancy between the various characteristics of the trees spread in the regions of Zawita and Atrush due to their differences in the locations of natural spread, whether geographical, height above sea level, or in different directions. This leads to a discrepancy in the natural resources of the site, which works on the growth of trees and the vitality of those trees, and this is what was mentioned by (Correia, *et al* 2017), and this is what we notice from the presence of greatly different densities, and we rely on this through the installation of these trees and the indicators of growth retarded in them, and it becomes clear to us from the distances between the trees and the number of trees in a unit (Younis , *et al* , 2021). The area includes good and medium-density sites, with a minimum of 258

(trees/ha), while the good sites reach 1182 (trees/ha), that is, there is a standard deviation between trees and the number of trees that reaches (267.61). This also applies to the distances between trees, while we find that there are also differences in the average total height of the sample trees. The range ranges between (4.01-13.86) and a standard deviation of (2.9). This corresponds to the average height of the crown center of the sample trees included in the study area. At low and high densities, we notice that the decrease in the crown center and its height ranged from (0.4-5.55) m and with a standard deviation of (1.25), from the above, you can see that the differences in heights were reflected in the average diameters of the trees for the study samples, which ranged between (7.1-27.2) cm, and a standard deviation that matches the deviation mentioned in the height of the trees. It seems that these densities were large, and the deviation was 6.11, while we find that the area surface area of the crown coverage of trees per unit area was consistent with their previously mentioned characteristics, as well as the presence of a large standard deviation of up to 43014.22 and a wide range of minimum and maximum values for the surface area.

(121492.6- 284808.3) As for the leaf area index, which is one of the very important indicators in measuring the vitality and growth of trees and evaluating the various physiological processes that occur in trees, it ranged between (1.21491-2.84808) with a standard deviation of (0.4301), as mentioned(Unger, et al. 2013) stated that the values of the leaf area index are an indicator of the vitality and development of trees, while(Pandey, and Singh, (2011) indicated that the surface area of tree leaves has a close relationship with the length and width of the crown and the height of the crown center, and it is also of great importance in the various physiological processes that take place inside the tree. The surface area of tree leaves is a botanical indicator of the changes occurring in tree growth temporally and spatially, as well as to evaluate the effectiveness of the physiological processes that occur within the crown canopy of forest trees (Sebastiani, *et al* 2023) (Kaushik, *et al* 2021).

Leaf area index (LAI)

The leaf area index (LAI) of tree leaves represents the amount of absorption by tree leaves of the falling rays of solar light that are used in photosynthesis processes within the leaf cells and are responsible for all primary production processes carried out by the tree. These measures are of high importance from an environmental and physiological standpoint. This gives us the possibility of monitoring plant covers and their development from one period to another, knowing the vitality of trees and their current growth, and anticipating future growth (Xu, et al 2020), so knowing the leaf area index gives the observer of plant covers positive and negative indicators of that direction in which it is heading, and this can be done by preparing equations.

A mathematical link between the leaf area index of trees per unit area and the variables of the arboretum, which are the average diameter and height of the trees in that arbor, as well as the distances between trees and their number per unit area. For this reason, samples amounting to (30) samples were taken from the trees of the pine, and the leaf area index for them was estimated with the variables in These samples were used using regression methods available in the statistical system (statgraphics), and we arrived at the following equations in Table (3).

Table (3): Leaf area index equations for pine trees and some statistical measures in the regions of Zawita, Atrush, and Sarsang.

N0.	MODEL	R^2	S.E	M.A.E
1	LAI = exp $^{(-1.17332 + 0.00477404*SA)}$	0.66	0.252037	0.196109
2	LAI = 0.152611 + 0.00357917*SA	0.71	0.168926	0.13221
3	LAI = 0.0132013*SA^0.792607	0.71	0.167967	0.131579
4	LAI = 0.162651 + 0.00358707*SA - 0.00138376*DM	0.71	0.172369	0.131294
5	LAI = 0.212619 + 0.00368307*SA - 0.00468816*HM	0.71	0.170568	0.126268
6	LAI = 0.757489 + 0.00475331*SA - 0.16596*SP	0.88	0.10794	0.0780925
7	LAI = 0.707183 + 0.0120838*DM + 0.00475683*SA - 0.176213*SP	0.89	0.105449	0.0768778
8	LAI = 0.00004506*(SA*N)^0.867231	0.65	0.185596	0.146685
9	LAI = -0.127227+0.0275159*(SA)^0.680633	0.71	0.171287	0.131197
10	LAI = -0.172656+0.115216*(SA)^0.514904-0.0784938*SP^1.33301	0.90	0.103836	0.0715438

From observing Table (3), we found that in forest stand of Zawita, atrush and sarsang two equation (6,7) were equations with multiple linear regression, and they represent the leaf area index as a dependent variable, while the average diameter of the tree and the number of trees per unit area were the independent variables, which are related to the leaf area index by a factor Determine R^2 (0.89-0.88), respectively, and also gave a value for the standard error attributed to the rate and the average absolute error (0.105449, 0.10794) (0.0768778, 0.0780925), respectively. From the above, we see that we can use these two equations after checking them graphically because the statistical measures of Both the coefficient of determination and the standard error were acceptable, and to check them graphically, we used residual analysis to observe whether there was an autocorrelation between the independent observations in the model for (7,6), as in the Figure (2).

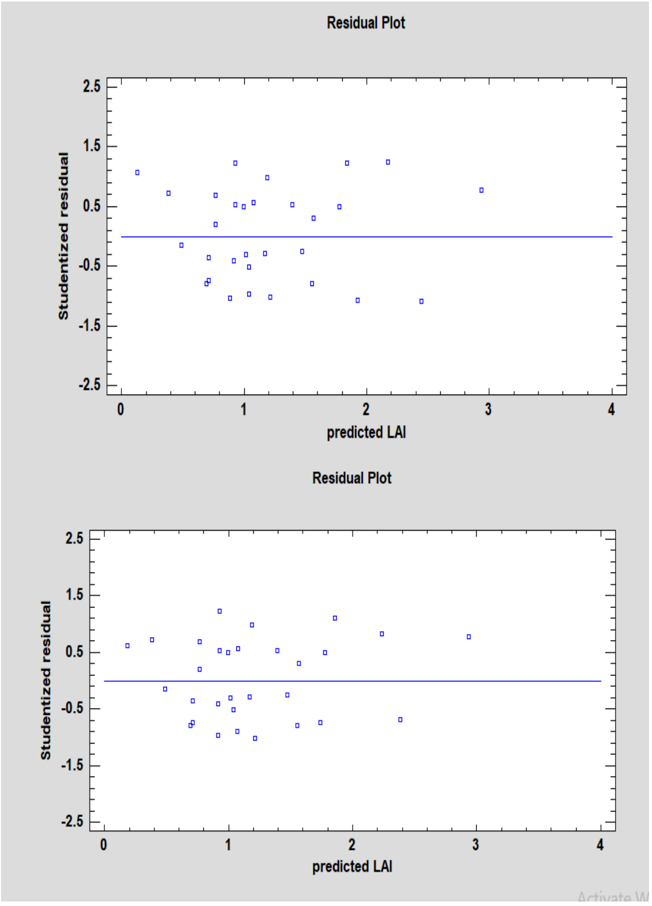

Figure (2): Distribution of random deviations between the real values and the estimated values of the leaf area index (LAI) for the pine trees growing in the areas of Zawita, Atrush, and Sarsang according to equations (6,7).

We find in Figure (1) that the random deviations are distributed normally and there is no correlation shown in Figure (1) in both equations, which indicates that these two equations are valid for use, but we need the relatively better equation, so it was found that the deviation of the equation The seventh had a positive deviation (1.5) and a negative deviation (1.3), while the (6) equation gave the smallest positive as well as negative deviation. This indicates that the (5) equation is relatively better, so we used the test (Ohtomo, and Nakajima, 1956), which is based on drawing a line. A straight line at an angle of 45 degrees bisects the angle of the origin and shows the relationship between the estimated and true values of the paper area guide for the study samples and observing the distribution of points in the straight line for the study samples and the distribution of points in the straight line randomly and with approximately equal distances. This indicates the possibility of guessing the equation with high accuracy and this is what you see in the Figure (3). Therefore, equation (6) was used to estimate the leaf area index based on the average tree diameter and the number of trees per unit area, as in Table (4). From Table (4), it appears to us that there is a strong relationship between the distances between trees, the surface area of the tree, and the index of leaf area, meaning that there is a relationship between the size and index of leaf area, and this is what was indicated by (Younis, 2021).

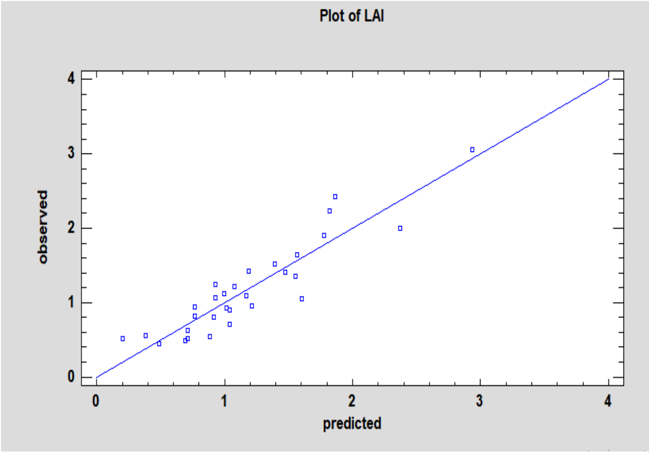

Figure (3): The relationship between the estimated and actual values of the leaf area index for naturally growing pine trees in the regions of Zawita, Atrush, and Sarsang.

Table (4): leaf area index per unit area for naturally growing pine trees in the regions of Zawita, Atrush, and Sarsang.

SA/m^2	SP/m						
	3	3.5	4	4.5	5	5.5	6
250	1.4479	1.3649	1.2819	1.1989	1.1160	1.0330	0.9500
300	1.6855	1.6026	1.5196	1.4366	1.3536	1.2706	1.1877
350	1.9232	1.8402	1.7573	1.6743	1.5913	1.5083	1.4253
400	2.1609	2.0779	1.9949	1.9119	1.8290	1.7460	1.6630
450	2.3985	2.3156	2.2326	2.1496	2.0666	1.9836	1.9007
500	2.6362	2.5532	2.4702	2.3873	2.3043	2.2213	2.1383
550	2.8739	2.7909	2.7079	2.6249	2.5420	2.4590	2.3760
600	3.1115	3.0286	2.9456	2.8626	2.7796	2.6966	2.6137
650	3.3492	3.2662	3.1832	3.1003	3.0173	2.9343	2.8513
700	3.5869	3.5039	3.4209	3.3379	3.2549	3.1720	3.0890
750	3.8245	3.7416	3.6586	3.5756	3.4926	3.4096	3.3267
850	4.2999	4.2169	4.1339	4.0509	3.9679	3.8850	3.8020
900	4.5375	4.4545	4.3716	4.2886	4.2056	4.1226	4.0396
950	4.7752	4.6922	4.6092	4.5263	4.4433	4.3603	4.2773
1000	5.0129	4.9299	4.8469	4.7639	4.6809	4.5980	4.5150
1050	5.2505	5.1675	5.0846	5.0016	4.9186	4.8356	4.7526
1100	5.4882	5.4052	5.3222	5.2392	5.1563	5.0733	4.9903

We note from the table that the surface area of the tree's leaves varies with the number of trees and the distances between the trees. If we have an arboretum with distances of (3*3) m between the trees and the surface area of the tree's leaves is (300) m2, we find that the leaf area index is estimated at (1.6855), but when the distances between the trees increase to (4.5*4.5). (m) At the same surface area of the tree, the surface area index decreases to (1.4366), while it increases at the same distance between trees (3 * 3) m, and when the surface area of the tree is (750) m2, it becomes (3.8245). This is what we notice in the stages of tree growth, in trees. In young trees, the leaf area index value is low and increases with increasing growth in the tree until it reaches advanced stages of maturity (Pande, and Singh, 2011) (Zou, *et al* 2020).

CONCLUSIONS

We recommend using the mathematical equations that were chosen to estimate the surface area of the tree and arbor and the dry weight of tree leaves to estimate the leaf area index for pine trees, as well as monitoring the vitality of trees through the leaf area index during successive periods, as well as determining the productivity of different sites in different locations. We also recommend using arboretum variables, such as distances between trees, average diameter, and height, in estimating the arboretum's leaf area using ground inventory methods.

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CONFLICT OF INTEREST

The researcher supports the idea that this work does not conflict with the interests of others.

قياسات دليل المساحة الورقية لمشاجر الصنوبر البروتي في شمال العراق

معن بشار شيخو [1]، مزاحم سعيد البك [2]، محمد يونس العلاف [3]
قسم الغابات / كلية الزراعة والغابات / جامعة الموصل / الموصل / العراق [1،2،3]

الخلاصة

يتم التعبير عن المساحة السطحية للأوراق اشجار المشجر التي تقوم بعملية التركيب الضوئي بدليل المساحة الورقية، ففي مشاجر الصنوبر البروتي ذات الكثافات المختلفة، استخدمت الطريقة المباشرة لجمع البيانات الحقلية من (30) عينة عام 2022م. ومنها اخذت قياسات القطر عند مستوى الصدر لكل عينة والارتفاع الكلي وارتفاع مركز التاج وعرض التاج وعدد الأشجار، ومن خلال البيانات الحقلية والتحليل المختبري للعلاقات بين تركيب عناصر المشجر , لوحظ ان دليل المساحة الورقية أظهر علاقة عكسية مع المسافات بين الاشجار وان زيادة المسافة بين الاشجار يخفض التغطية التاجية للأشجار وبالتالي ينعكس على دليل المساحة الورقية للمشجر, ففي الكثافات الواطئة ينخفض ويزداد بزيادة كثافة المشجر, وهذا ينطبق كذلك على العلاقة بين الوزن الجاف للأوراق والمسافات بين الاشجار, حيث اظهرت علاقة عكسية وكذلك كان واضحا ايضا للعلاقة بين الوزن الجاف للأوراق ومتوسط القطر والارتفاع للأشجار في ذلك المشجر, ولقد تم التوصل الى مجموعة من المعادلات التي تم اختبارها بالمقاييس الاحصائية المتعددة والمتمثلة بكل من معادلة الوزن الجاف لأوراق اشجار الصنوبر لوحدة المساحة ومعادلة المساحة السطحية لأوراق اشجار الصنوبر لوحدة المساحة وايضا دليل المساحة الورقية لأشجار الصنوبر البروتي.

الكلمات المفتاحية: دليل المساحة الورقية، المساحة السطحية للأوراق.

REFERENCES

Ariza-Carricondo, C., Di Mauro, F., de Beeck, M. O., Roland, M., Gielen, B., Vitale, D., ... and Papale, D. (2019). A comparison of different methods for assessing leaf area index in four canopy types. *Central European Forestry Journal*, 65(2), 67-80. https://doi.org/10.2478/forj-2019-0011

Ahmed, A. J & M.S. Younis. (2020). Effect of stand variables on the relationship between leaf area, sapwood area ratio, of Populus nigra L. Grown in Zakho region, University of Mosul, College of Agriculture and Forestry, /.

Al-Allaf, M.Y, M.S., Al-Bek, and M.A., Qader (2023) Determine Canopy Gaps for Atrush Forest using Remote Sensing Data, IOP Conf. Series: Earth and Environmental Science, https://doi.org/10.1088/1755-1315/1213/1/012114

Chen, J. M., Rich, P. M., Gower, S. T., Norman, J. M., and Plummer, S. (1997). Leaf area index of boreal forests: Theory, techniques, and measurements. *Journal of Geophysical Research: Atmospheres*, 102(D24), 29429-29443. https://doi.org/10.1029/97JD01107

Correia, A. C., Mutke, S., and Silva, J. (2017). Variability of specific needle area in Pinus pinea L. with environment resources availability: light, water and nutrients. *Mediterranean pine nuts from forests and plantations. Zaragoza: CIHEAM*, 43-47. https://om.ciheam.org/article.php?IDPDF=00007240

Davidson, D. P., Hall, D. P., Peddle, R. J., and Johnson, R. L. (2000). A comparison of optical methods for estimating Leaf Area Index in forest stands. *In 22nd Annual Canadian Remote Sensing Symposium* (pp. 653-659). https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/20646.pdf

Dewey, J. C., Roberts, S. D., and Hartley, I. (2006). A comparison of tools for remotely estimating leaf area index in loblolly pine plantations. *In 13th Biennial Southern Silvicultural Research Conference* (p. 71). https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs092/gtr_srs092-015-dewey.pdf

Fang, H., Baret, F., Plummer, S., and Schaepman-Strub, G. (2019). An overview of global leaf area index (LAI): Methods, products, validation, and applications. *Reviews of Geophysics*, 57(3), 739-799. https://doi.org/10.1029/2018RG000608

Fleck S, Raspe S, Cater M, Schleppi P, Ukonmaanaho L, Greve M, Hertel C, Weis W and Rumpf, S. (2012). Methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forest. ISBN:978-3-926301-03-1. www.icp-forests.org/Manual.htm.

Hartoyo, A. P. P., Pamoengkas, P., Mudzaky, R. H., Khairunnisa, S., Ramadhi, A., Munawir, A., and Sunkar, A. (2022). Estimation of vegetation cover changes using normalized difference vegetation index (NDVI) in Mount Halimun Salak National Park, Indonesia. *In IOP Conference Series: Earth and Environmental Science* (Vol. 1109, No. 1, p. 012068). IOP Publishing. https://doi.org/10.1088/1755-1315/1109/1/012068

Kaushik, P., Pati, P. K., Khan, M. L., and Khare, P. K. (2021). A quick and simple method for estimating leaf area by leaf weight. *International Journal of Botany Studies*, 6(6), 1286-1288. https://www.botanyjournals.com/assets/archives/2021/vol6issue6/6-6-212-441.pdf

Kurdy, R. M. and M. A. Saeed, (2021). Yield estimation for natural uneven aged Pinus brutia Ten. Plantation grown in Atrush region, University of Mosul, College of Agriculture and Forestry, M.Sc. Thesis.

Ohtomo, E., and Nakajima, I. (1956). Research on the method of forest inventory by the use of aerial photographs. *Journal of the Japanese Forestry Society*, 38(10), 379-388.

Pandey, S. K., and Singh, H. (2011). A simple, cost-effective method for leaf area estimation. *Journal of botany*, 2011 (2011), 1-6. https://doi.org/10.1155/2011/658240

S. Khosravi, S., Namiranian, M., Ghazanfari, H., and Shirvani, A. (2012). Estimation of leaf area index and assessment of its allometric equations in oak forests: Northern Zagros, Iran. *Journal of Forest Science*, 116-122. https://doi.org/10.17221/18/2011-JFS

Salim, M.Y., A.J. Mohammed and M.S. Younis, (2023) A WEIGHT RELATIVE DENSITY MODEL TO PINUS BRUTIA TEN. STANDS IN NORTHERN OF IRAQ, Int. J. Agricult. Stat. Sci. Vol. 19, DOI: https://doi.org/10.59467/IJASS.2023.19.1479

Sebastiani, A., Salvati, R., and Manes, F. (2023). Comparing leaf area index estimates in a Mediterranean forest using field measurements, Landsat 8, and Sentinel-2 data. *Ecological Processes*, 12(1), 1-13. http:/Comparing leaf area index.pdf

Solís-Silvan, R., Sanchez-Gutiérrez, F., Islas-Jesús, R. E., Gerónimo-Torres, J. D. C., Pozo-Santiago, C. O., and Sanchez-Díaz, B. (2022). Estimation of the leaf area index from Sentinel images in Eucalyptus grandis W. Hill plantations. *Revista Tecnología en Marcha*, 35(2), 39-47. http://dx.doi.org/10.18845/tm.v35i2.5535

Turner, D. P., Acker, S. A., Means, J. E., and Garman, S. L. (2000). Assessing alternative allometric algorithms for estimating leaf area of Douglas-fir trees and stands. *Forest Ecology and Management*, 126(1), 61-76. https://doi.org/10.1016/S0378-1127(99)00083-3

Unger, M., Homeier, J., and Leuschner, C. (2013). Relationships among leaf area index, below-canopy light availability and tree diversity along a transect from tropical lowland to montane forests in NE Ecuador. *Tropical Ecology*, 54(1), 33-45. http:/publications.goettingen-research

Xu, J., Quackenbush, L. J., Volk, T. A., and Im, J. (2020). Forest and crop leaf area index estimation using remote sensing: Research trends and future directions. *Remote Sensing*, 12(18), 2934. https://doi.org/10.3390/rs12182934

Younis, M.Y., A. J. Mohammed and M. A. Saeed, (2021). Effect of stand density on the biomass productivity of Populus nigra L. growing in Nineveh Plantation, *J. of Kirkuk Univ. for Agri. Sci*., Vol. (12) No. (1) 2021 Appendix. https://www.iasj.net/iasj/article/211613

Zou, J., Hou, W., Chen, L., Wang, Q., Zhong, P., Zuo, Y., ... and Leng, P. (2020). Evaluating the impact of sampling schemes on leaf area index measurements from digital hemispherical photography in Larix principis-rupprechtii forest plots. *Forest Ecosystems*, 7(1), 1-18. https://doi.org/10.1186/s40663-020-00262-z